

Electronic Switching

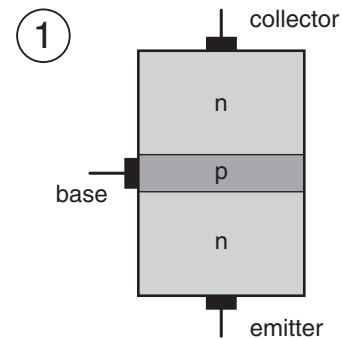


Topic

The transistor

Introduction

Transistors are important components of electronic circuits because they use relatively small input signals to control circuits carrying large currents. Transistors are used as switches and amplifiers. The type of transistor used in this experiment (see diagram 1 below) is made of three layers of semiconductor material – two layers of n-type, containing an excess of negative charge carriers (electrons) on either side of a thin layer of p-type material containing an excess of positive charge carriers. The transistor has three terminals (base, emitter, and collector) – one to each semiconductor layer. In the first part of this experiment, you will examine current flows through a transistor when no input signal is applied. You will do this by testing the resistance between the terminals of the transistor. In the second part of the experiment, you will apply a small voltage to the base terminal of the transistor and show how this affects current flowing through the transistor. (You will do this by adjusting a variable resistor connected between the terminals of the transistor; this divides the supply voltage between the terminals of the transistor.)



Structure of the transistor

Time required

40 minutes

Materials

Part A

2N3053 transistor

multimeter

suitable connection system (e.g., a breadboard see Experiment 9.01)

Part B

2N3053 transistor

10 ohm resistor (0.25 watts)

100 ohm resistor (0.25 watts)

560 ohm resistor (0.25 watts)

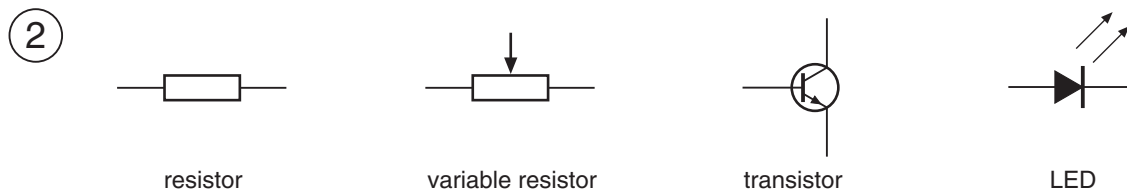
1 kilohm variable resistor (0.25 watts)

5 mm (0.2 in.) LED (any color)

9 volt battery and snap connector
multimeter
clip leads or suitable connection system
(e.g. a breadboard – see Experiment 9.01)

If you are using a breadboard, you will also need three short lengths of connecting wire (e.g., approximately no. 20 gauge, insulated, tinned copper wire with about 0.5 cm of insulation stripped away at each end).

Electronic components are available from suppliers such as RadioShack (<http://www.radioshack.com>). The appearance of the components may vary among suppliers. Simple wiring diagrams and circuit diagrams are given in this experiment to show the arrangement of the components. Diagram 2 below shows the symbols used in the circuit diagrams in this experiment.



Symbols used in circuit diagrams

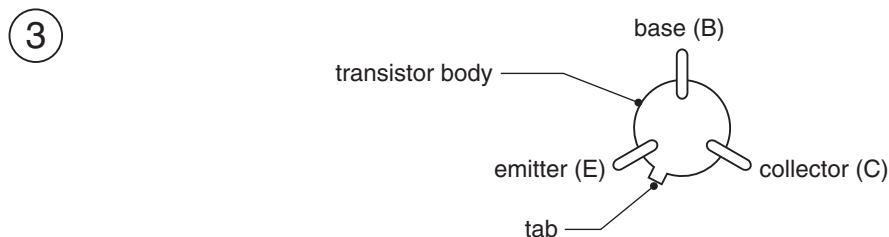
Safety note



Do not use an electrical outlet.

Procedure

Part A: Current flow with no voltage applied



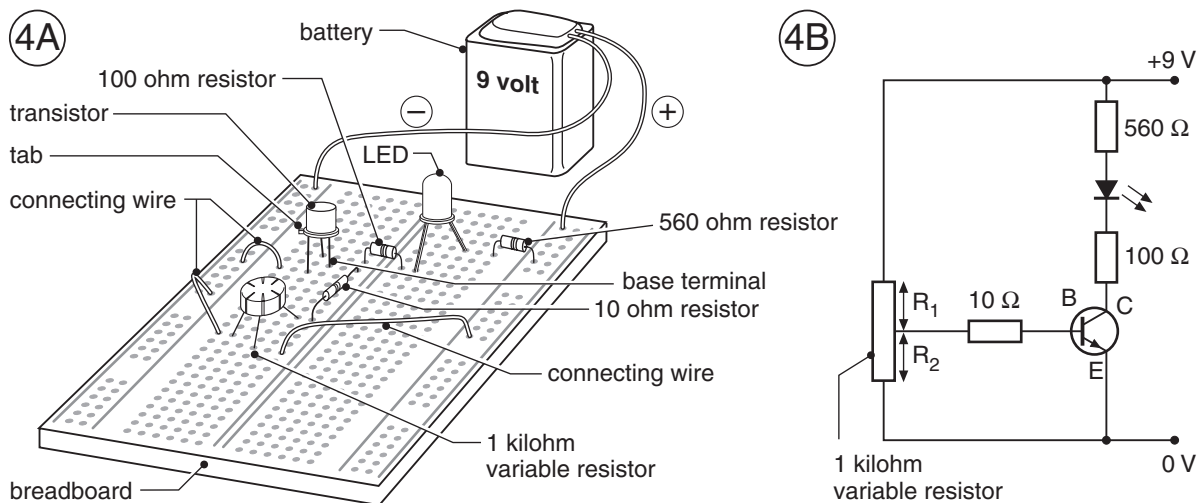
Terminals of a transistor

1. Use diagram 3 above to help you identify the terminals of the transistor.
2. Insert the terminals of the transistor in the breadboard (make sure they are not in holes that are connected beneath the surface).
3. Adjust the multimeter to read resistance.
4. Touch the red and black probes of the multimeter to the terminals of the transistor in sequence, being careful not to touch the body of the transistor with the probes. Most of the readings will be very high and may not register

on the multimeter; some of the results will be lower and only register briefly. Record your results in data table A below as either HIGH or LOW.

DATA TABLE A		
Red probe	Black probe	Result (HIGH or LOW)
E	C	
E	B	
C	E	
C	B	
B	E	
B	C	

Part B: Current flow with voltage applied



Wiring diagram (A) and circuit diagram for Part B

1. Connect the equipment as shown in diagram 4 above with the adjuster in the center of the variable resistor turned as far as possible in a counterclockwise direction (i.e. R_2 is zero).
2. Adjust the multimeter to read voltage and carefully touch one probe to the base wire of the transistor and the other probe to the emitter wire. Enter the multimeter reading in data table B on the next page for the initial value (i.e., transistor is OFF).
3. Turn the variable resistor in a clockwise direction (this increases R_2) until the LED just lights. Carefully touch one of the probes of the multimeter to the base wire of the transistor and the other probe to the emitter wire. Enter the multimeter reading in data table B for the base-emitter voltage when the transistor is ON.

DATA TABLE B	
	Multimeter reading (volts)
Base-emitter voltage when transistor is OFF	
Base-emitter voltage measured when transistor is ON	

Analysis

Part A: Current flow with no voltage applied

1. Which connections produced a low resistance reading?
2. What do the resistance readings suggest about current flow through the transistor?

Part B: Current flow with voltage applied

1. What was the value of the base-emitter voltage when the transistor was OFF?
2. What was the base-emitter voltage when the transistor was ON and the LED was glowing?

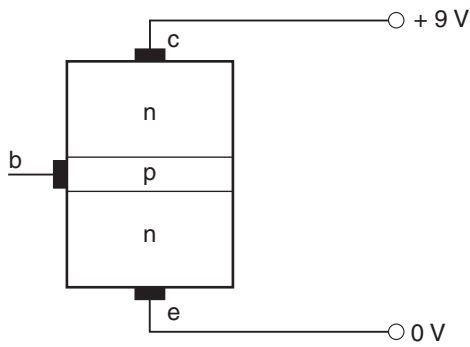
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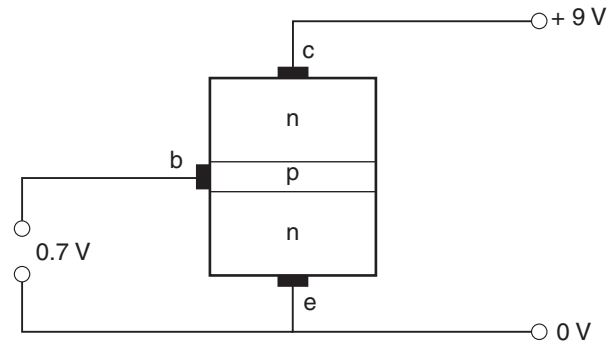
Part A: Current flow with no voltage applied

1. There is a low resistance reading in two cases:
 - (i) When the red probe touches the base terminal (B) and the black probe touches the emitter terminal (E).
 - (ii) When the red probe touches the base terminal (B) and the black probe touches the collector terminal (C).
2. A low resistance reading indicates that current will flow. A high value shows that current will not flow. Current will flow through a transistor from the base to the emitter or from the base to the collector, but not from the collector to the emitter.

The collector (C) and emitter (E) are the connections to the n-type layers. The base (B) is the connection to the p-type layer in the center. If a voltage is applied as shown in the diagram on the left on the next page, no current flows from C to E through the transistor. This is because the upper (p-n) junction is reverse biased (i.e., it behaves like a diode, which will not conduct in that direction).



Voltage applied to upper p–n junction



Voltage applied to lower p–n junction

Part B: Current flow with voltage applied

1. The initial value of the base–emitter voltage is zero.
2. Our voltage reading was 0.6–0.7 volts. This is the usual potential difference between the base and emitter required to allow the transistor to conduct.

If a voltage is applied between base and emitter to the lower p–n junction of a transistor (as in the diagram above right), electrons are able to flow from the emitter to the base. As the base is very thin, the electrons pass through to the collector. This allows the top junction to conduct, and current then passes through the transistor. The small voltage applied to the base therefore allows a larger current to flow through the transistor.

The voltage applied between the terminals of a transistor can be varied by changing the values of resistors connected between its terminals. When designing circuits using transistors, it is important to know what value of resistors to use to supply the appropriate voltage to the transistor terminals. The values can be calculated using Ohm’s Law:

$$\text{Base–emitter voltage} = \text{Value of supply voltage} \times \frac{R_2}{R_1 + R_2}$$

where R_1 is the value of the resistor connected between the base and the collector, and R_2 is the value of resistor connected between the base and the emitter.

To switch the transistor on, the base–emitter voltage should be 0.6–0.7 volts. If R_1 is much bigger than R_2 , the base–emitter voltage is very small. If R_1 is much less than R_2 , the base-emitter voltage approaches the value of the supply voltage.